

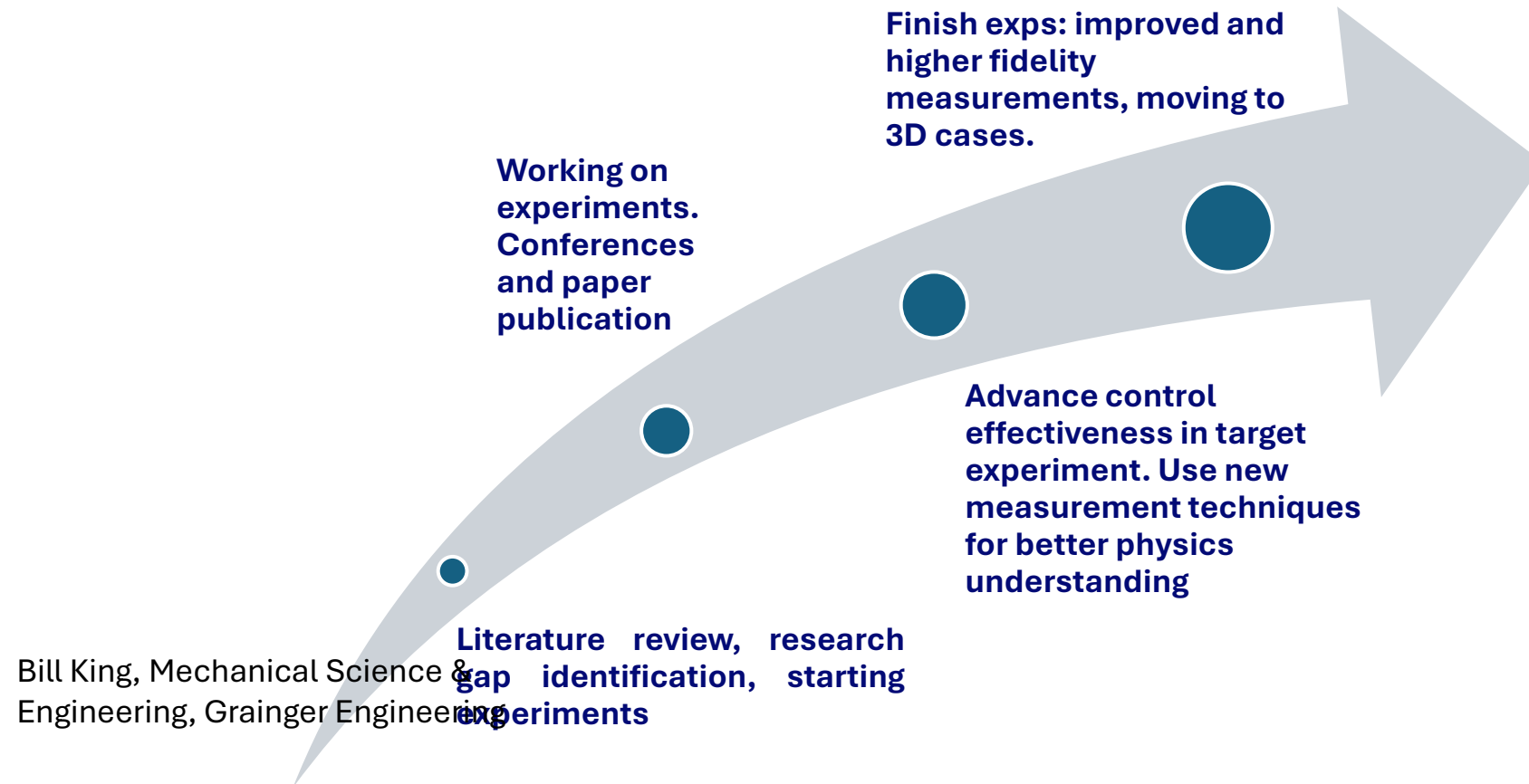
Enhancing Turbulent Flow control via data fusion

PhD Student:
Víctor Duro de la Merced

Supervisor/s:
**Carlos Sanmiguel Vila,
PhD; Rodrigo Castellanos, PhD.**

**PhD Aerospace Engineering UC3M
Doctoral Meetings 2026
2nd and 3rd June 2026**

- Research on the complex problem of **controlling turbulent flows**.
- **Data fusion**, **data-driven** methods, **ROM identification** for effective control strategies.
- Impinging jets, heat transfer



- Research on the complex problem of controlling turbulent flows.
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OBJECTIVE:

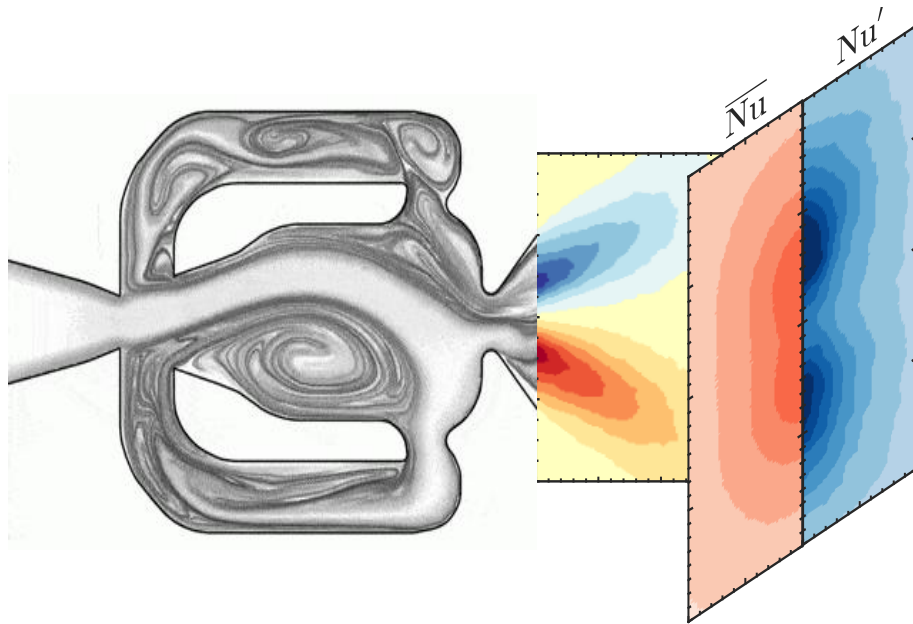
Better understanding of **Flow Control in turbulent, impinging jets**, via **data fusion** (IR + velocity measurements); and **Low Order representation** of flows (POD, MDS, others), for enhanced heat transfer.

Passive control case: Impinging Sweeping Jet

Active control case: Impinging Turbulent Jet with control

Impinging, Sweeping Jet

- Interaction between flow and the consequent heat transfer at the wall.
- Reconstruct velocity fields from wall-measurements in **perpendicular** planes.
- **Extended Proper Orthogonal Decomposition** (EPOD) offers a particularly well suited and robust method for data fusion.
- Databases of different temporal resolution.



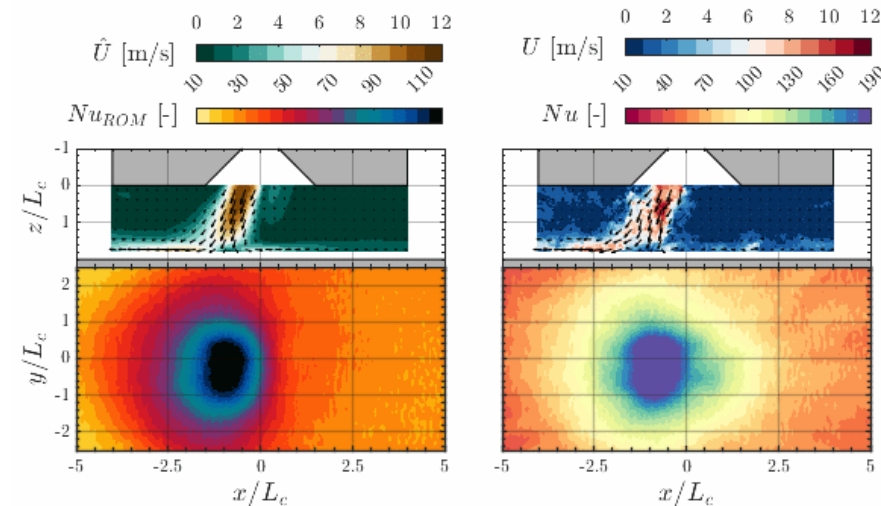
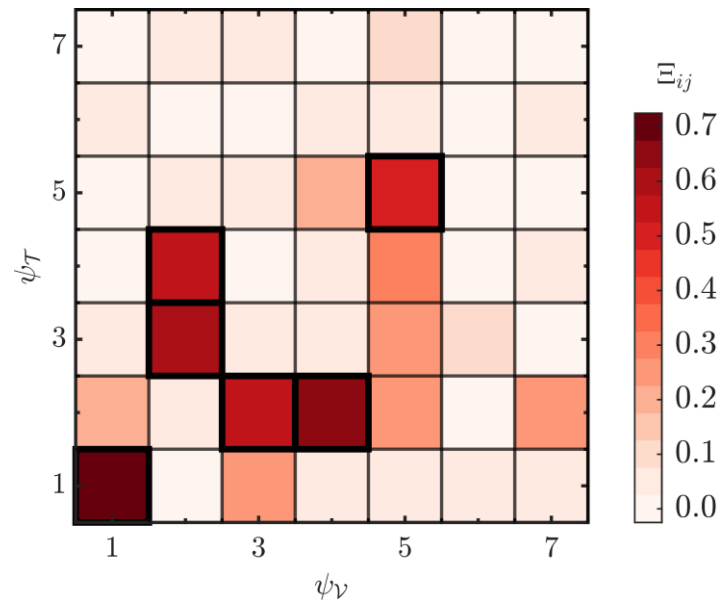
We investigate:

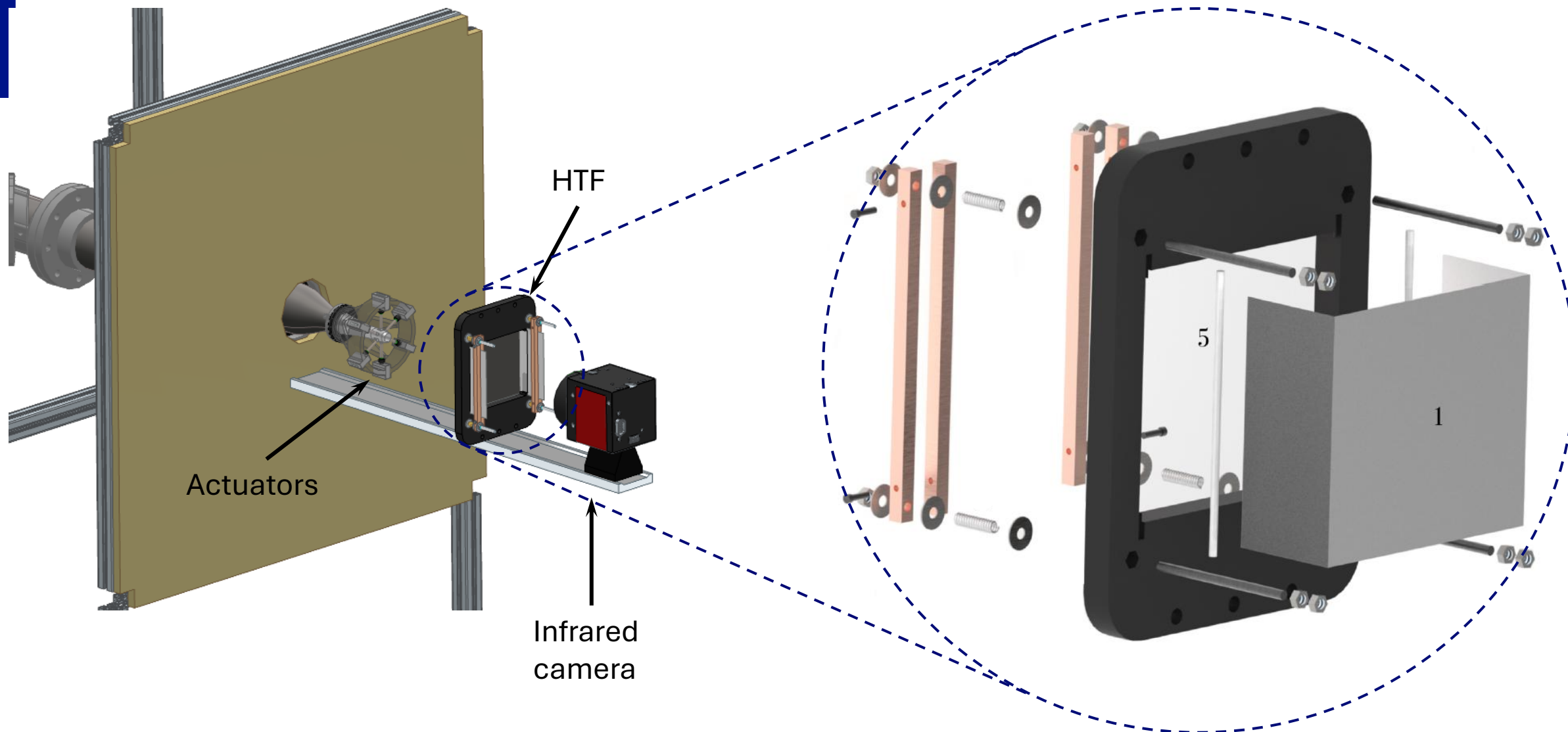
- (1) Does **linear correlation** between momentum and heat transfer hold locally?
- (2) Can we **reconstruct the dominant velocity dynamics** of the Flow from wall heat transfer measurements from EPOD correlation?

Impinging, Sweeping Jet

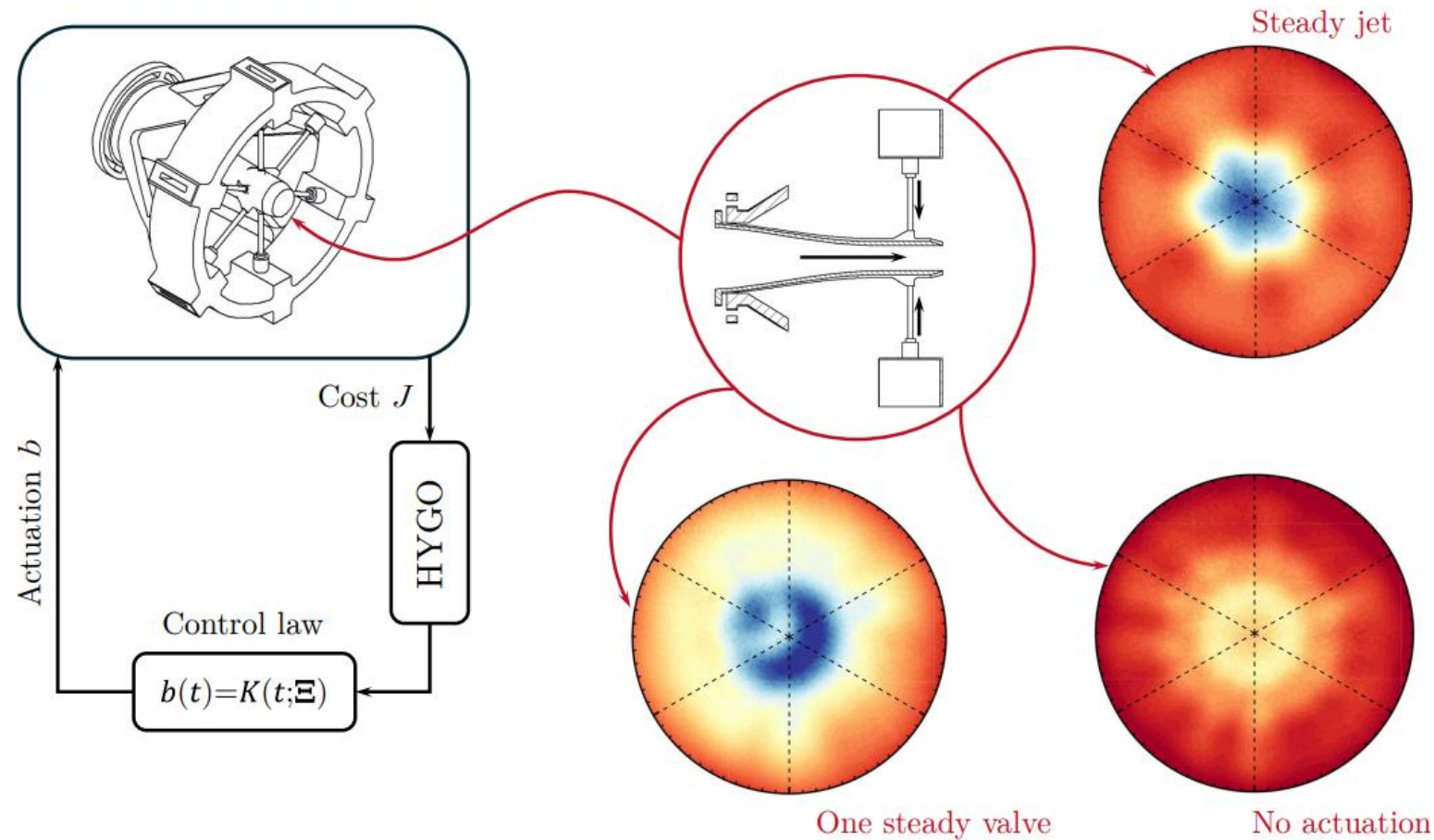
- **V. Duro.**, M. Raiola, R. Castellanos, & C. Sanmiguel Vila, *Estimating the flow dynamics from instantaneous wall heat transfer in an impinging sweeping jet*. Experiments in Fluids, (2026)

- **Compact correlated subspace** within the first 5 temporal modes.
- We infer velocity from heat transfer measurements in perpendicular planes
- We take into account **jitter** in the reconstruction.
- We **reconstruct** dominant flow dynamics.

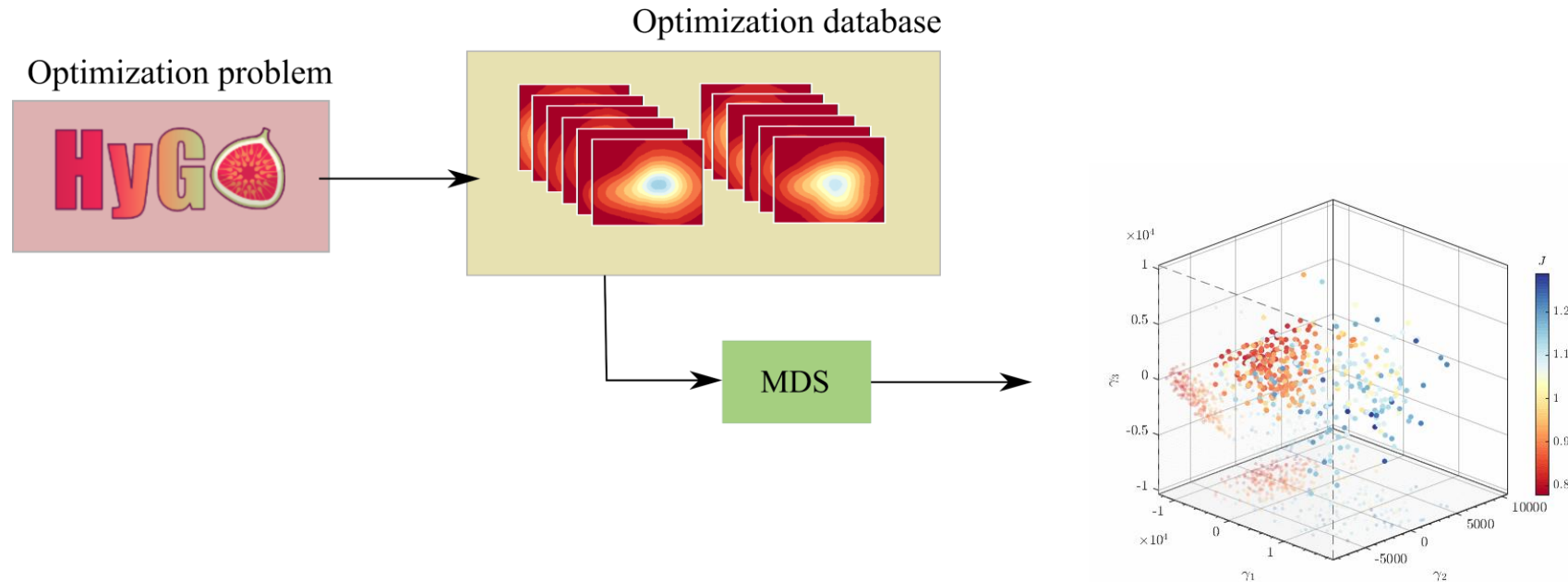




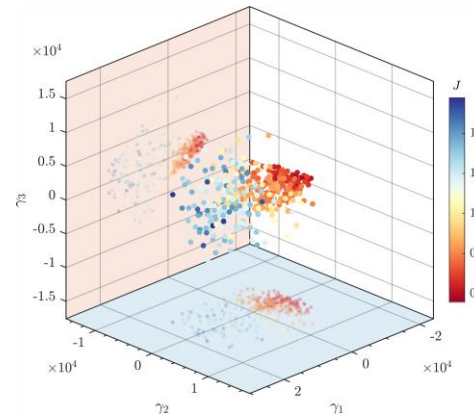
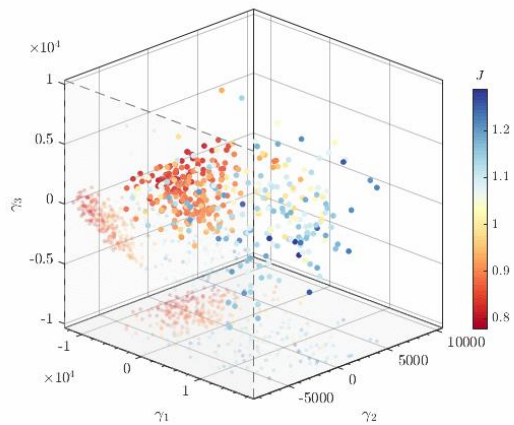
- Optimization in Impinging jet transfer through Genetic Algorithms (HYGO):



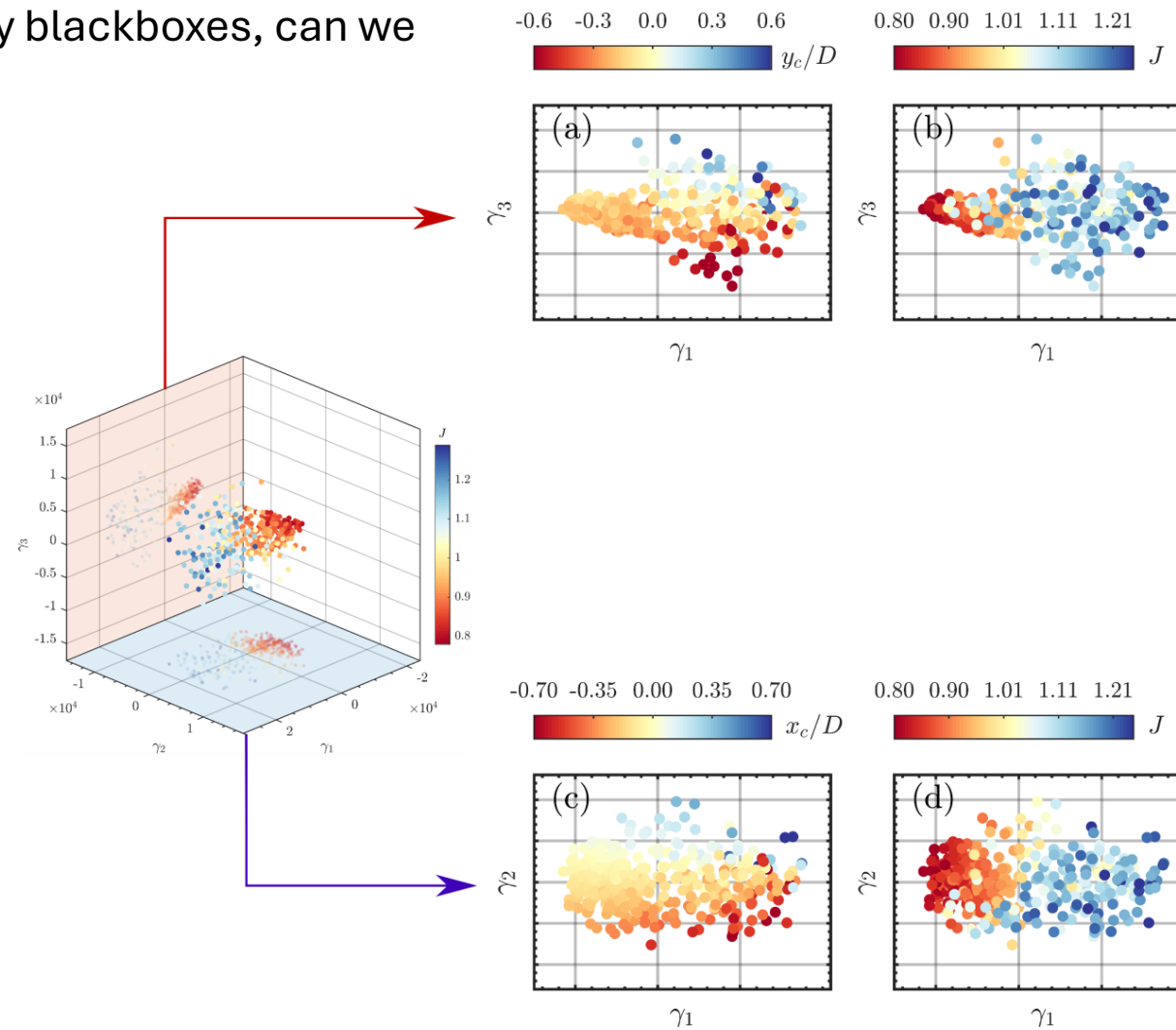
ML optimizations are typically blackboxes, can we understand the results ?



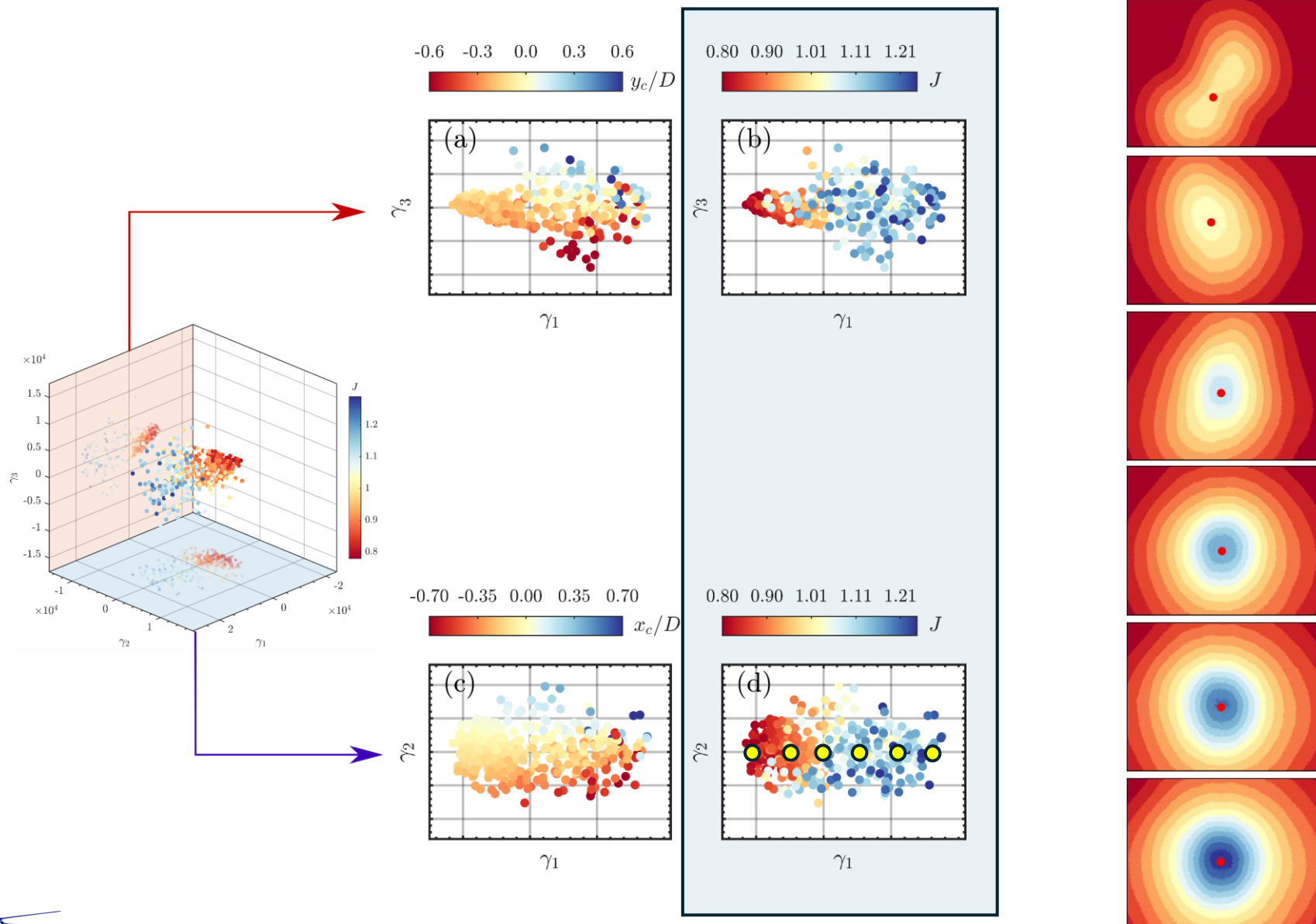
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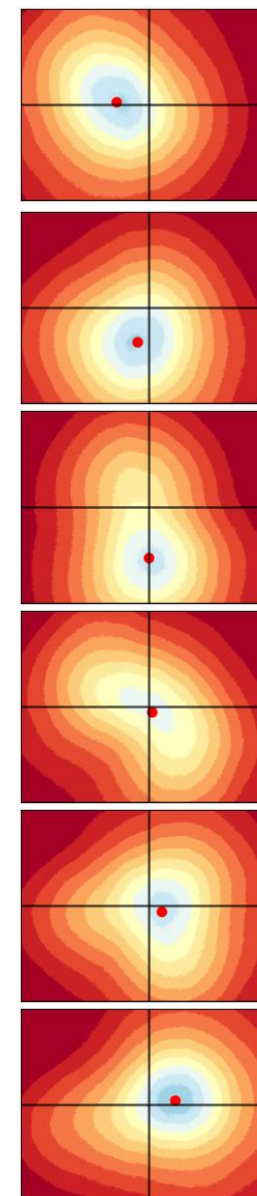
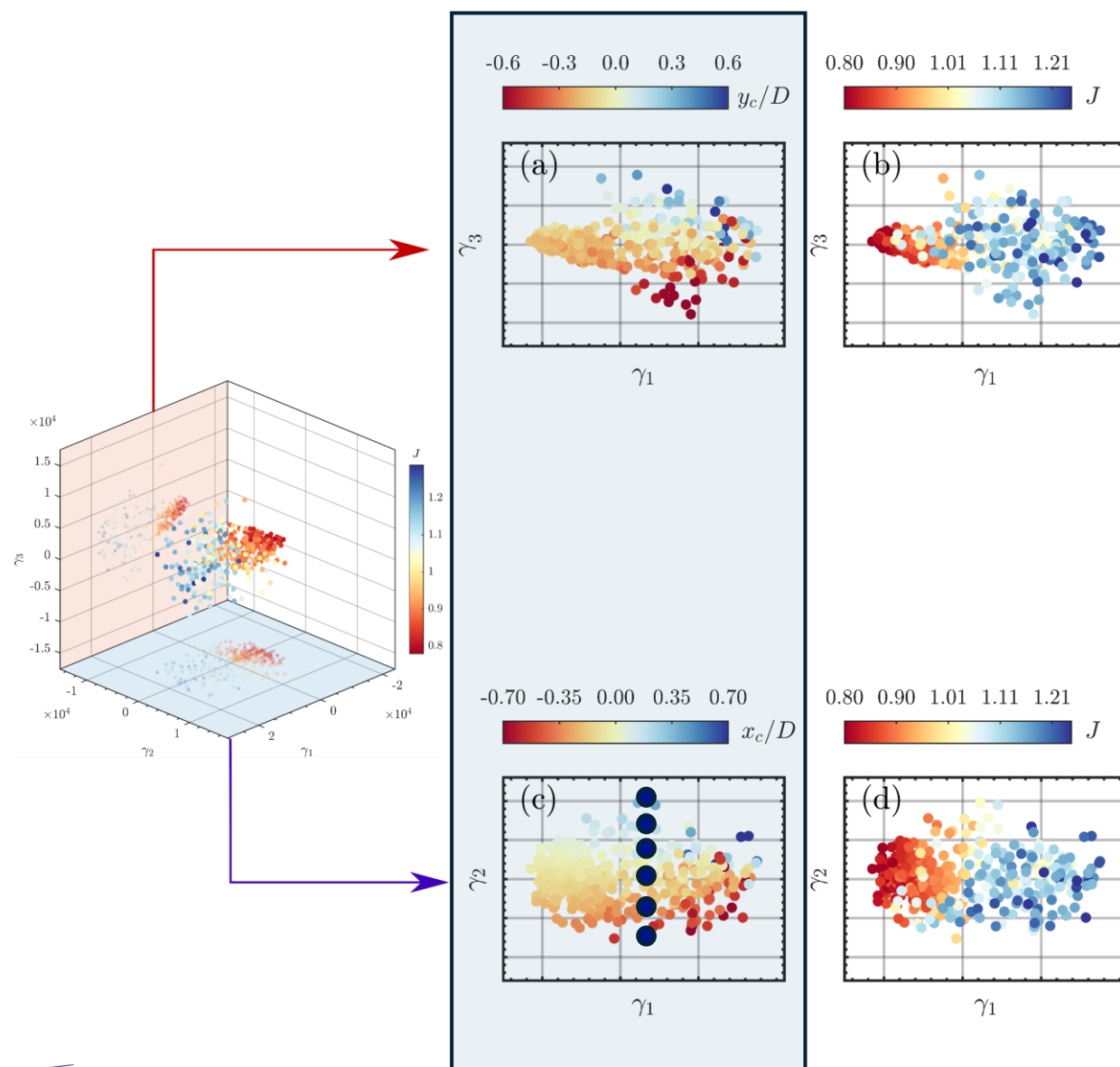
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Standard, turbulent Impinging Jet - Results

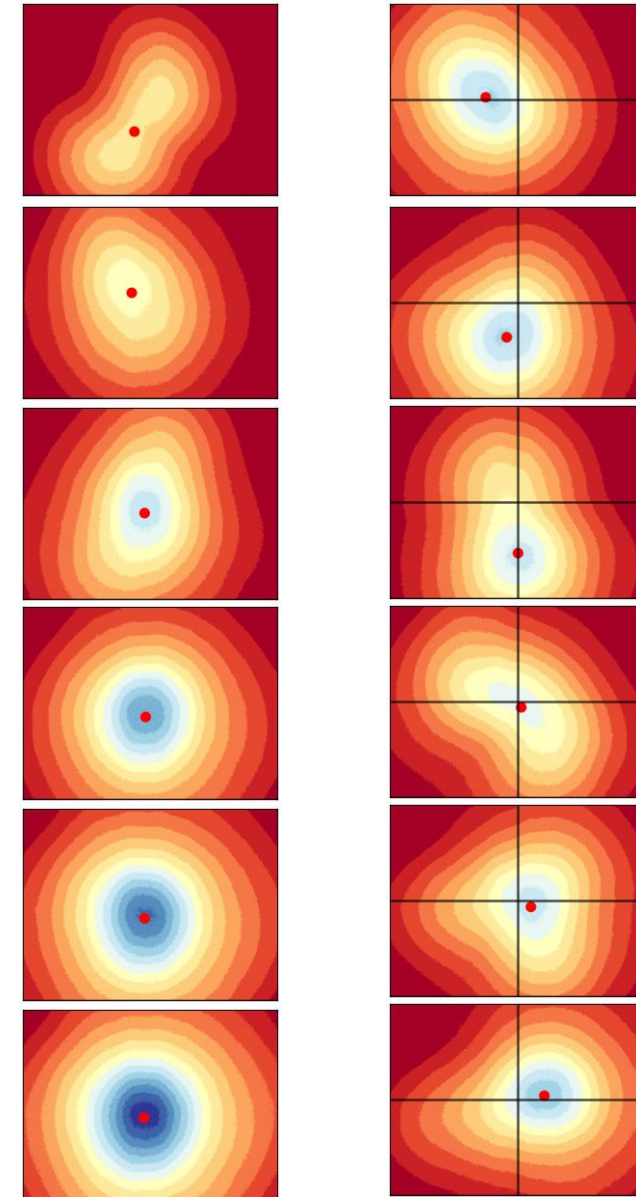


Standard, turbulent Impinging Jet - Results



We reduce complex fluid data into a simple, low-dimensional 3D space.

- **Decoupled Control:** Separates cooling intensity and effectiveness γ_1 from spatial steering (γ_2, γ_3). Changing intensity will not shift the targeting.
- **Closed-Loop Targeting:** Uses frequency for cooling magnitude and phase shifts for localized steering.
- **Faster Optimization:** Eliminating symmetric redundancies drastically accelerates search convergence.



- **V. Duro**., M. Raiola, R. Castellanos, & C. Sanmiguel Vila, *Estimating the flow dynamics from instantaneous wall heat transfer in an impinging sweeping jet*. Experiments in Fluids (2026)
- **V. Duro**, I. Robledo, J. Alfaro, R. Castellanos, C. Sanmiguel Vila, & A. Ianiro. *Enhancing impinging-jet heat transfer with pulsed mini-jets: optimisation and low-dimensional analysis*. International Journal of Mass and Heat Transfer (in preparation).
- Additional paper on Sweeping Jet (JFM) + Additional paper on Impinging Jet planned for this year (?).
- 5 Conference contributions past year:
 - **V. Duro**, M. Raiola, R. Castellanos & **C. Sanmiguel Vila***, Time-resolved flow field reconstruction from wall heat-transfer measurements in impinging sweeping jets in *16th International Symposium on Particle Image Velocimetry*, 2025, Tokyo.
 - **V. Duro**, I. Robledo, J. Alfaro, R. Castellanos & **C. Sanmiguel Vila***, Impinging jet convective heat transfer enhancement using genetic algorithm control in *16th 21st International Symposium on Flow Visualization* 2025, Tokyo.
 - **V. Duro***, J. Alfaro, I. Robledo, R. Castellanos & C. Sanmiguel Vila, Open-loop optimisation of jet mixing for convective heat transfer using genetic algorithm control, in *17th International Conference on Fluid Control, Measurements, and Visualization* 2025, Delft
 - **V. Duro***, M. Raiola, R. Castellanos & C. Sanmiguel Vila, Unveiling the Interaction between Flow Field and Wall Heat Transfer in Impinging Sweeping Jets, in *Spanish Fluid Mechanics Conference* 2025, Málaga.
 - **J. Alfaro***, I. Robledo, **V. Duro**, R. Castellanos & C. Sanmiguel Vila, Open-loop optimization of jet mixing for convective heat transfer using genetic algorithm control, in *Spanish Fluid Mechanics Conference* 2025, Málaga.

- **V. Duro.**, M. Raiola, R. Castellanos, & C. Sanmiguel Vila, *Estimating the flow dynamics from instantaneous wall heat transfer in an impinging sweeping jet*. Experiments in Fluids (2026)
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- Additional paper on Sweeping Jet (JFM) + Additional paper on Impinging Jet planned for this year (?).
- 1 conference expected this year:
 - **V. Duro***, J. Alfaro, I. Robledo, R. Castellanos, Andrea Ianiro & C. Sanmiguel Vila, Data-driven low-dimensional interpretation of pulsed impinging-jet heat-transfer control, in *European Drag Reduction and Flow Control Meeting – EDRFCM 2026*, Madrid.

+ Other additional research lines (Background Oriented Schieleren on heated jet; Drag reduction on road vehicles)

I. Robledo, J. Alfaro, V. Duro, A. Solera-Rico, R. Castellanos & C. Sanmiguel Vila, *Reducing base drag on road vehicles using pulsed jets optimized by hybrid genetic algorithms*, Physics of Fluids, 38, 4, 1 (2026)

Questions?

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Acknowledgments:

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